Details of reconstructive surgery and amputations carried out in districts with below (low volume) and above (high volume) the average rate of arterial reconstructions in the Oxford region. Values are numbers or proportions (percentages)

	High volume	Low volume	Statistics χ^2	df	P value
Referrals from outside the district	10/67 (15)	2/46 (4·3)	2·197	1	0·138
Balloon angioplasty before reconstructive surgery	23/67 (34)	3/41 (7·3)	8·729	1	0·0031
Types of infrainguinal graft:					
Femorotibial graft	17 (25)	4 (11)	23·943	2	0·0001
Femoropopliteal:					
Vein	31 (46)	4 (11)			
Prosthesis	19 (28)	27 (77)			
Amputation rate per 100 000 population per year (95% confidence interval)	6·1 (4·0 to 8·2)	10·3 (7·4 to 13·2)	5·365	1	0·021
Ratio of below knee to above knee amputations	2·6:1	1·1:1	2·37	1	0·124
Angiography before amputation	36/44 (82)	19/36 (53)	3·565	1	0·059
Surgical reconstruction before amputation	27/44 (61)	6/36 (17)	14·53	1	0·0001

and vascular reconstructions distal to the inguinal ligament over six months. Amputations for trauma or malignancy were excluded. A single datasheet was completed giving details of each procedure carried out, the indication, the patient's district of residence, where the operation was performed, and details of previous investigations or treatment.

At the end of six months all theatre records in participating districts were checked by one of the participants or an audit assistant. Additional forms were completed from the notes of those patients who had been omitted.

Completed forms for all patients identified by a subsequent check of theatre records were received from five districts, covering a total population of 1·9 million, two of these districts being high volume and three low volume, as defined above. Differences between centres in high and low volume districts were analysed by using a χ^2 test with correction for continuity.

Overall, data were collected for 137 reconstructions and 93 amputations, 79 of which were the first major amputation of that leg. These represent rates of 11·7, 9·6, and 8·2 procedures per 100 000 of the population respectively.

In the high volume districts more patients had been referred from outside the district, more reconstructive procedures were preceded by balloon angioplasty, and more reconstructive procedures entailed arterial bypass grafting to the calf or foot and use of autologous vein. These districts had a lower rate of amputation, a higher proportion of below knee amputations, and a higher proportion of patients who had undergone previous angiography or surgical treatment (table).

Comment

Access to vascular surgery is variable and depends on district of residence.[1] Our findings show that districts with high rates of distal arterial reconstructions do fewer amputations and that amputations are carried out more distally and are more likely to be preceded by investigations or surgical attempts to save the leg.

We conclude that an expansion in specialist vascular surgical services in the Oxford region and more widespread use of distal arterial reconstructive surgery would result in substantial reductions in the number of leg amputations with consequent savings in both disability and cost.[2] These findings are supported by studies elsewhere[3] and shed further light on the debate about the provision of specialist vascular surgical services.[4]

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Confounding and Simpson's paradox

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A common problem when analysing clinical data is that of confounding. This occurs when the association between an exposure and an outcome is investigated but the exposure and outcome are strongly associated with a third variable. An extreme example of this is Simpson's paradox, in which this third factor reverses the effect first observed.[1] This phenomenon has long been recognised as a theoretical possibility but few real examples have been presented.

Examples

Charig *et al* undertook a historical comparison of success rates in removing kidney stones.[2] Open surgery (1972-80) had a success rate of 78% (273/350) while percutaneous nephrolithotomy (1980-5) had a success rate of 83% (289/350), an improvement over the use of open surgery. However, the success rates looked rather different when stone diameter was taken into account. This showed that, for stones of <2 cm, 93% (81/87) of cases of open surgery were successful compared with just 83% (234/270) of cases of percutaneous nephrolithotomy. Likewise, for stones of ≥ 2 cm, success rates of 73% (192/263) and 69% (55/80) were observed for open surgery and percutaneous nephrolithotomy respectively.

The main reason why the success rate reversed is because the probability of having open surgery or percutaneous nephrolithotomy varied according to the diameter of the stones. In observational (non-randomised) studies comparing treatments it is likely that the initial choice of treatment would have been influenced by patients' characteristics such as age or severity of condition; so any difference between treatments could be accounted for by these original factors. Such a situation may arise when a new treatment is being phased in over time. Randomised trials are therefore necessary to demonstrate any treatment effect.

In another example Hand reported that the proportion of male patients in a psychiatric hospital seemed to fall slightly over time, from 46·4% (343/739) in 1970 to 46·2% (238/515) in 1975.[3] When the results were broken down according to patients' age, however, it was observed that the proportion of male patients had increased; from 59·4% (255/429) to 60·5% (156/258) among those aged <65 and from 28·4% (88/310) to 31·9% (82/257) among those aged ≥ 65.

The table shows another example, a study of mortality and diabetes (data from the Poole diabetic cohort[4]). In the study only 29% of the patients with

Survival by type of diabetes. Values are numbers (percentages)

Survival status	Type of diabetes: Non-insulin dependent	Insulin dependent	Total
All patients			
Censored	326 (60)	253 (71)	579
Dead	218 (40)	105 (29)	323
Total	544 (100)	358 (100)	902
Patients aged ≤40			
Censored	15 (100)	129 (99)	144
Dead	0	1 (1)	1
Total	15 (100)	130 (100)	145
Patients aged >40			
Censored	311 (59)	124 (54)	435
Dead	218 (41)	104 (46)	322
Total	529 (100)	228 (100)	757

insulin dependent diabetes died compared with 40% of the patients with non-insulin dependent diabetes. However, non-insulin dependent diabetes usually develops only after the age of 40.[5] Hence, when the diabetic patients are split into two groups (those aged ≤40 and those aged >40), it is found that in both groups a smaller proportion of patients with non-insulin dependent diabetes died compared with patients with insulin dependent diabetes.

Comment

All three examples incorporate the arbitrary dichotomisation of continuous variables. However, adjustment can be made by keeping the variables continuous. For the Poole diabetic cohort, a Cox proportional hazards survival model with just type of diabetes indicates that insulin dependent diabetes gives a significantly better prognosis for survival than non-insulin dependent diabetes (relative risk 0·69 (95% confidence interval 0·54 to 0·87)). However, correcting for age (by entering it concurrently into the model with type of diabetes) switches this risk so that the risk for insulin dependent diabetes is greater than for non-insulin dependent diabetes (relative risk 1·15 (0·91 to 1·46)).

Thus, a problem arises when the variable of interest is expected to be confounded with another factor (such as type of diabetes and age) or when there is an important imbalance of a factor at the different levels of the variable of interest (such as an imbalance in the proportion of the sexes on two treatments). To accommodate this, the factor should also be included in a multiple regression or multiple logistic regression model together with the variable of interest or as a covariate in an analysis of variance.

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Deprivation and mortality in Glasgow: changes from 1980 to 1992

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Social class differentials in mortality in Britain increased between the early 1970s and early 1980s,[1] and various indicators of increasing social polarisation since 1980 suggest that these mortality differentials will have widened further.[2] Further widening is supported by analyses of area based mortality in the north of England which show that the differences in mortality between the most deprived and most affluent areas increased greatly between 1981 and 1991.[3] Preliminary analyses from Glasgow showed a similar picture.[4] We report the trends in socioeconomic mortality differentials in Greater Glasgow from 1980 to 1992.

Methods and results

Numbers of deaths by sex and 10 year age band were available for 1980-82 and 1990-92 for people aged 15-64 residing in the area covered by the Greater Glasgow Health Board. Using the 1981 and 1991 census populations for Greater Glasgow as denominators we calculated standardised mortality ratios and confidence intervals. The standardised mortality ratio for the whole of Glasgow in 1980-82 was taken as 100.

We assigned postcode sectors in Greater Glasgow to eight categories (neighbourhood types[4]) on the basis of a cluster analysis of 30 area based sociodemographic variables from the 1981 census. The categories ranged from NT1 (most affluent) to NT8 (most deprived). The same neighbourhood type categories were used for 1980-82 and 1990-92. The variables used to assign neighbourhood type included all those used in the Carstairs deprivation index[5] and other variables that allow better discrimination within deprived areas. The high overall levels of deprivation in Glasgow result in other indices consigning large proportions of the population to the lowest categories, thus reducing their discriminatory power.

We combined NT1 and NT2 to produce the affluent areas—those with high owner occupation levels, high rates of single and multiple car ownership, and a high proportion of professionals and non-manual workers. NT7 and NT8 were combined to produce the deprived areas—those with high local authority accommodation, high unemployment rates, and mainly unskilled occupations among those working. The percentage of the population of Greater Glasgow aged 15-64 living in the affluent areas was 21·8% in 1981 and 25·2% in 1991. The percentage living in deprived areas was 26·4% in 1981 and 23·6% in 1991.

The standardised mortality ratios were considerably higher for the deprived than affluent areas for both sexes, for the two age bands analysed, and for both periods (table). The ratios of standardised mortality ratios between the deprived and affluent areas increased substantially between 1980-82 and 1990-92 for both sexes and for all age groups. As a common standard was used for the two periods the change in standardised mortality ratio over time reflects change in mortality over the 10 years. For men aged 15-44 in the deprived areas mortality increased by 9% (95% confidence interval −4% to 26%). For 15-64 year olds in affluent areas mortality fell substantially: by 18% (10% to 26%) for men and 22% (11% to 30%) for women. Considerably smaller falls were seen in the